Waveguide Input/Output Methods

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Waveguide Input/Output Methods

A waveguide, as explained earlier in this chapter, operates differently from an ordinary transmission line. Therefore, special devices must be used to put energy into a waveguide at one end and remove it from the other end.

The three devices used to inject or remove energy from waveguides are PROBES, LOOPS, and SLOTS. Slots may also be called APERTURES or WINDOWS.

As previously discussed, when a small probe is inserted into a waveguide and supplied with microwave energy, it acts as a quarter-wave antenna. Current flows in the probe and sets up an E field such as the one shown in figure 1-39, view (A). The E lines detach themselves from the probe. When the probe is located at the point of highest efficiency, the E lines set up an E field of considerable intensity.

Figure 1-39A. - Probe coupling in a rectangular waveguide.

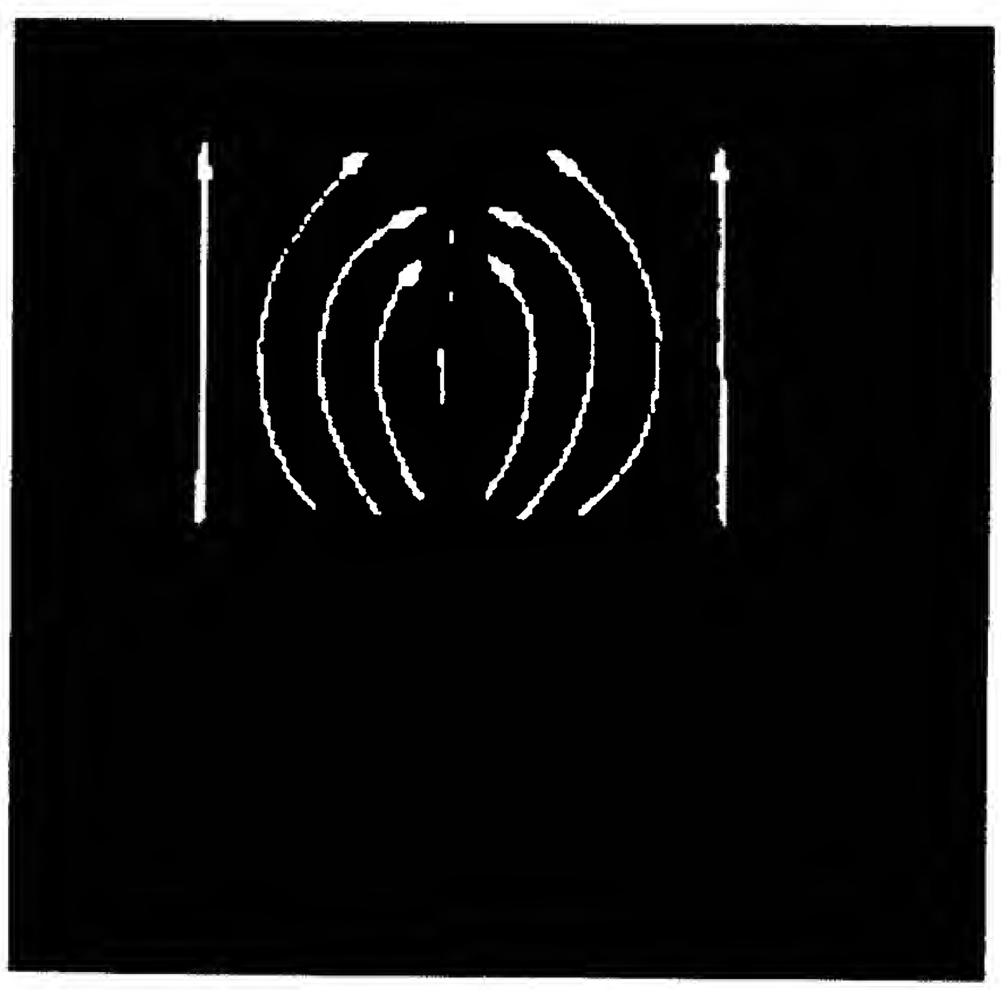

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Figure 1-39B. - Probe coupling in a rectangular waveguide.

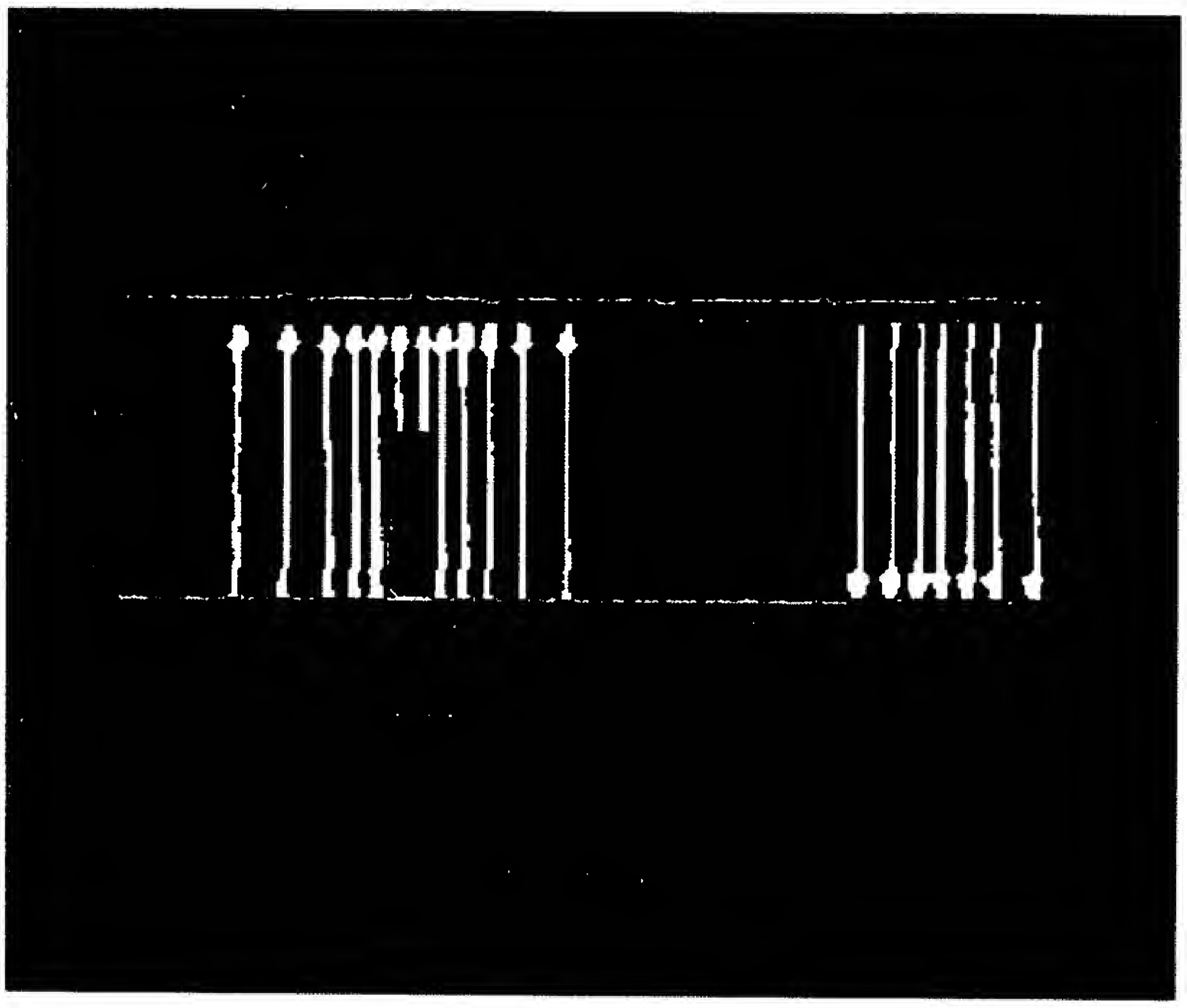


Figure 1-39C. - Probe coupling in a rectangular waveguide.

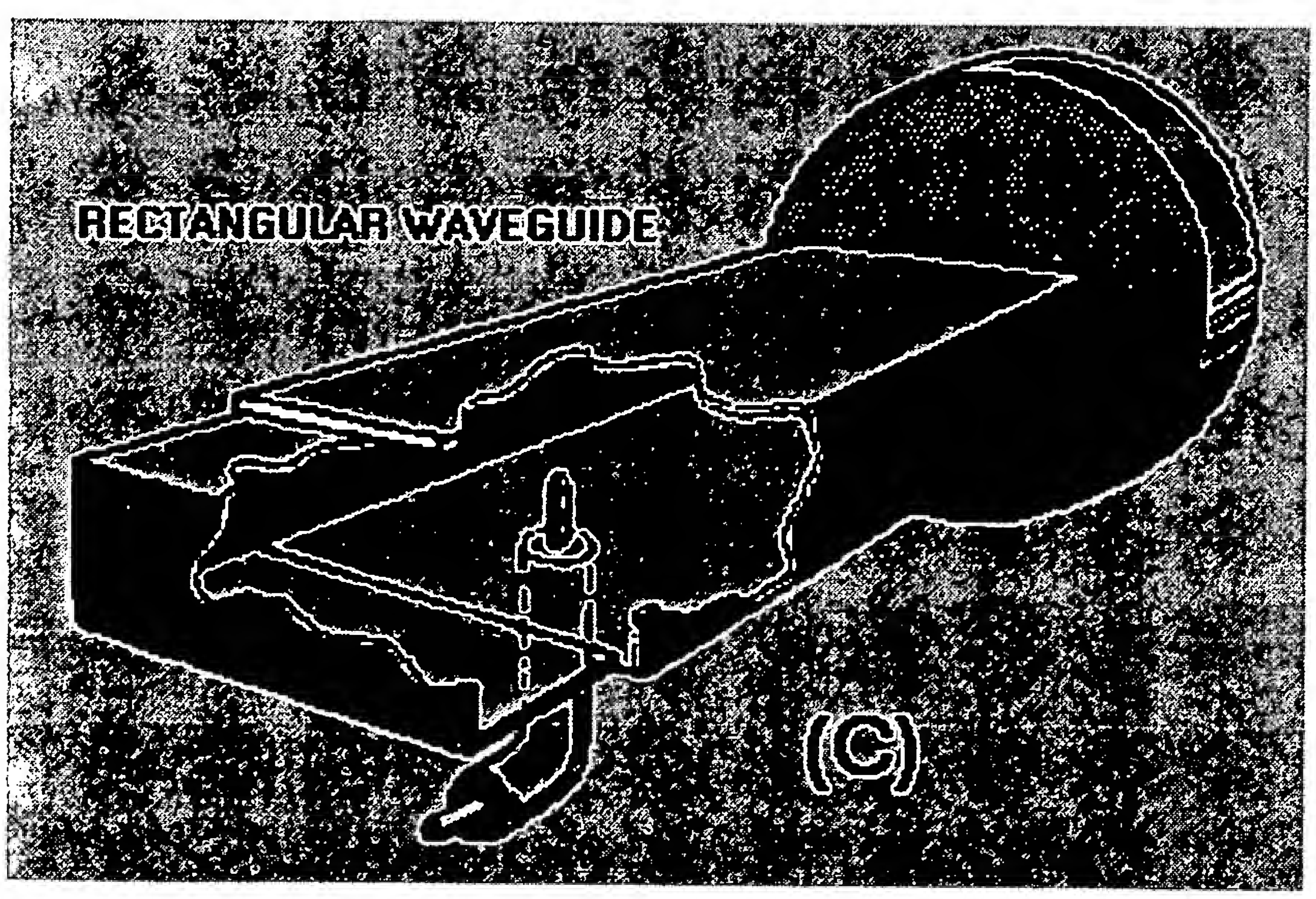
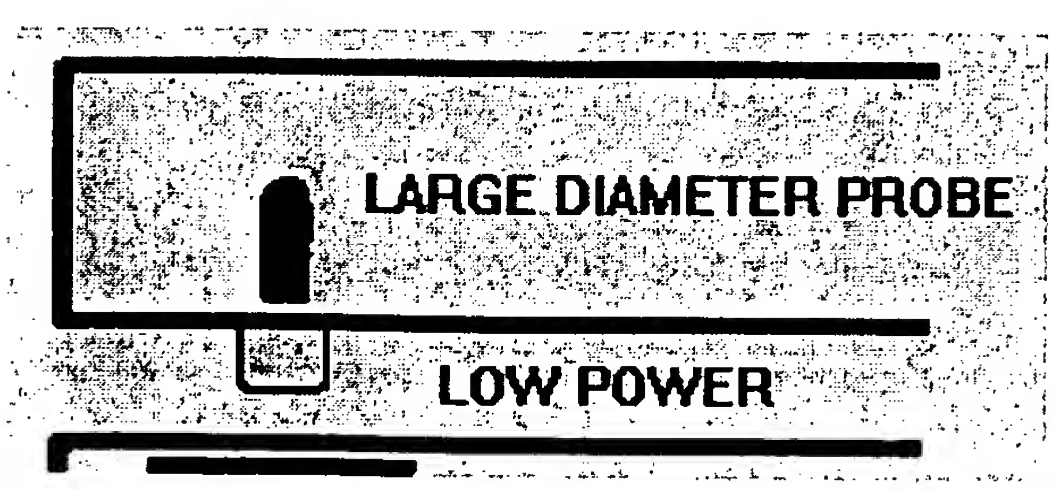
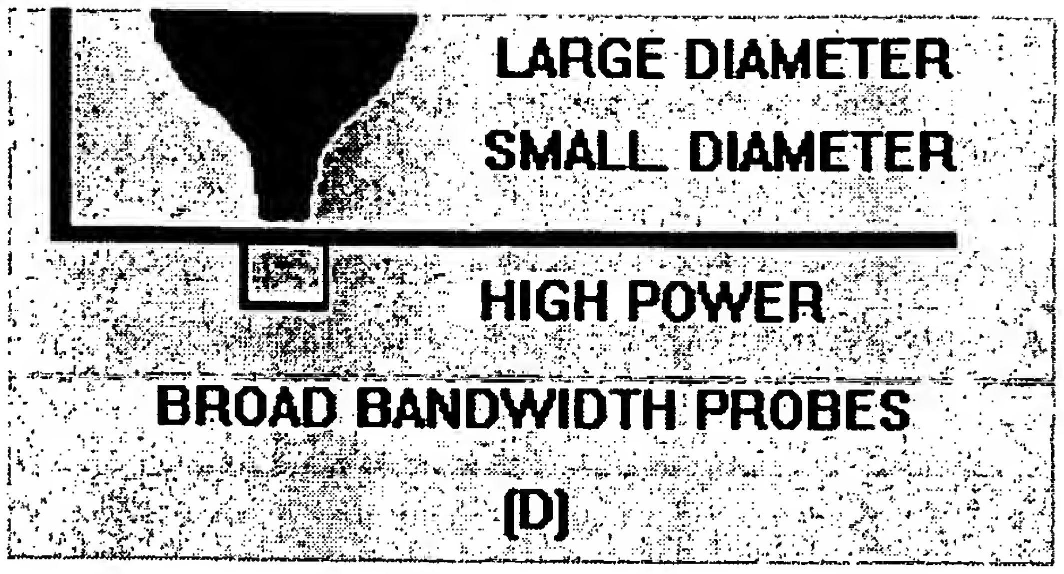


Figure 1-39D. - Probe coupling in a rectangular waveguide.





The most efficient place to locate the probe is in the center of the "a" wall, parallel to the "b" wall, and one quarter-wavelength from the shorted end of the waveguide, as shown in figure 1-39, views (B) and (C). This is the point at which the E field is maximum in the dominant mode. Therefore, energy transfer (coupling) is maximum at this point. Note that the quarter-wavelength spacing is at the frequency required to propagate the dominant mode.

In many applications a lesser degree of energy transfer, called loose coupling, is desirable. The amount of energy transfer can be reduced by decreasing the length of the probe, by moving it out of the center of the E field, or by shielding it. Where the degree of coupling must be varied frequently, the probe is made retractable so the length can be easily changed.

The size and shape of the probe determines its frequency, bandwidth, and power-handling capability. As the diameter of a probe increases, the bandwidth increases. A probe similar in shape to a door knob is capable of handling much higher power and a larger bandwidth than a conventional probe. The greater power-handling capability is directly related to the increased surface area. Two examples of broad-bandwidth probes are illustrated in figure 1-39, view (D). Removal of energy from a waveguide is simply a reversal of the injection process using the same type of probe.

Another way of injecting energy into a waveguide is by setting up an H field in the waveguide. This can be accomplished by inserting a small loop which carries a high current into the waveguide, as shown in figure 1-40, view (A). A magnetic field builds up around the loop and expands to fit the waveguide, as shown in view (B). If the frequency of the current in the loop is within the bandwidth of the waveguide, energy will be transferred to the waveguide.

For the most efficient coupling to the waveguide, the loop is inserted at one of several points where the magnetic field will be of greatest strength. Four of those points are shown in figure 1-40, view (C).

Figure 1-40A. - Loop coupling in a rectangular waveguide.

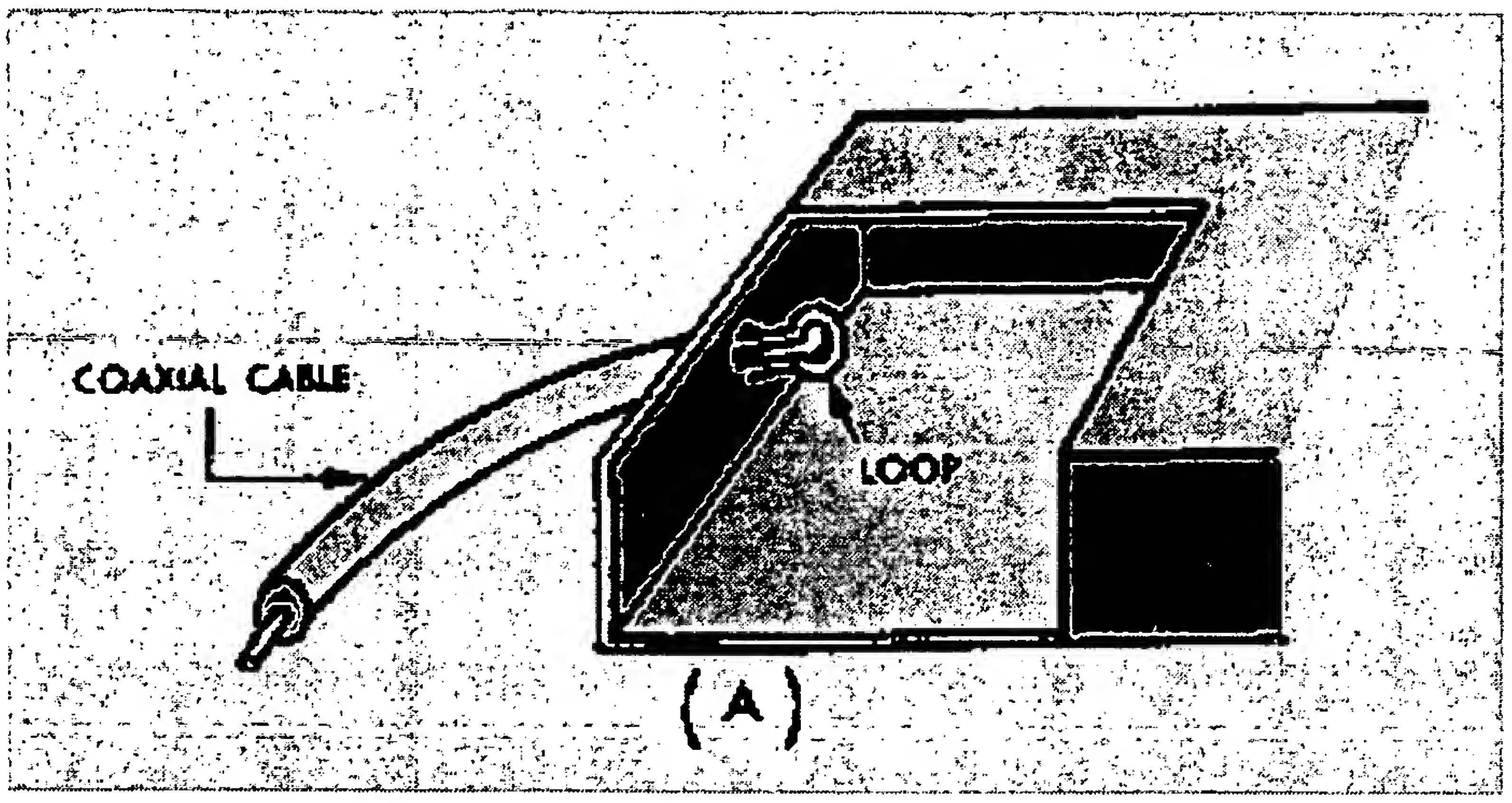


Figure 1-40B. - Loop coupling in a rectangular waveguide.

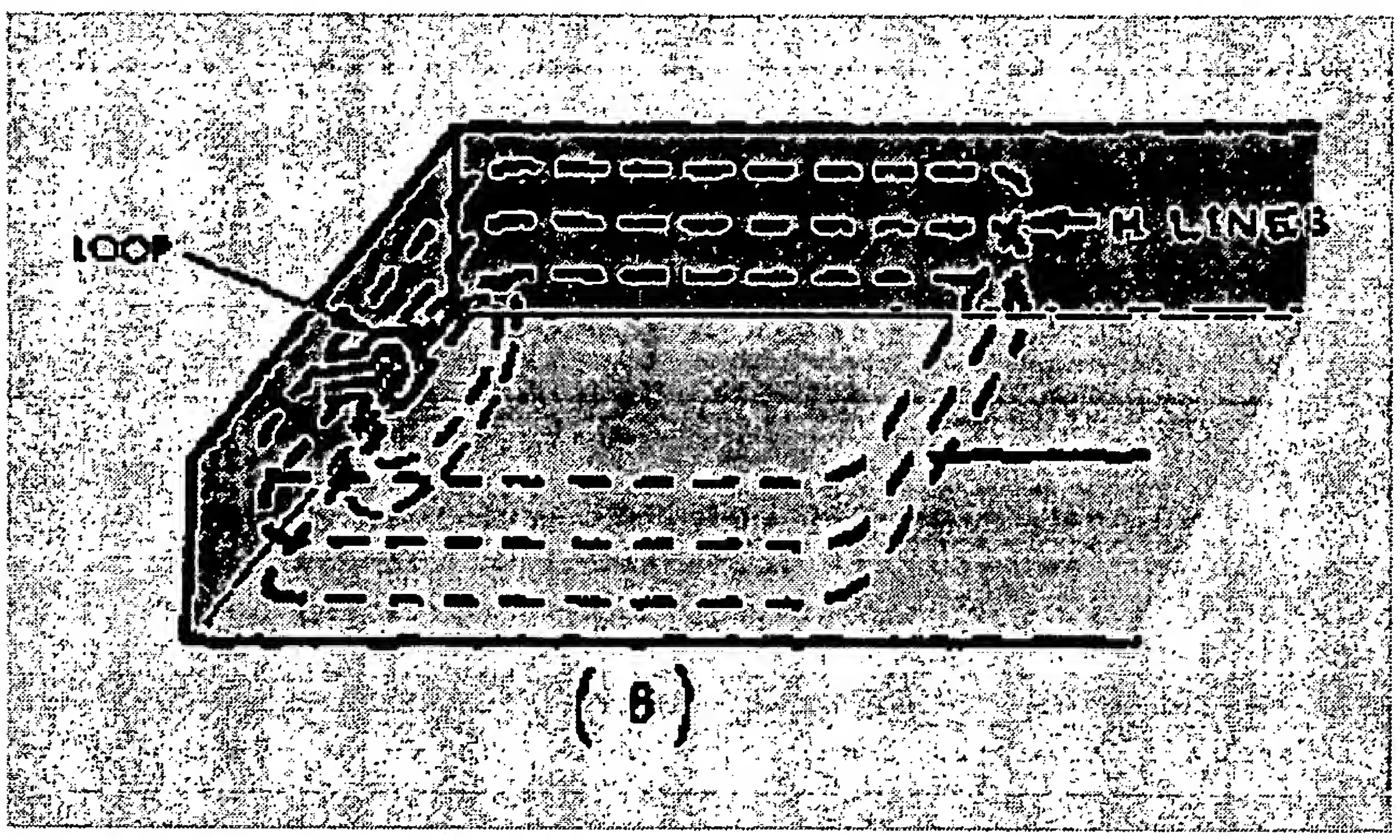
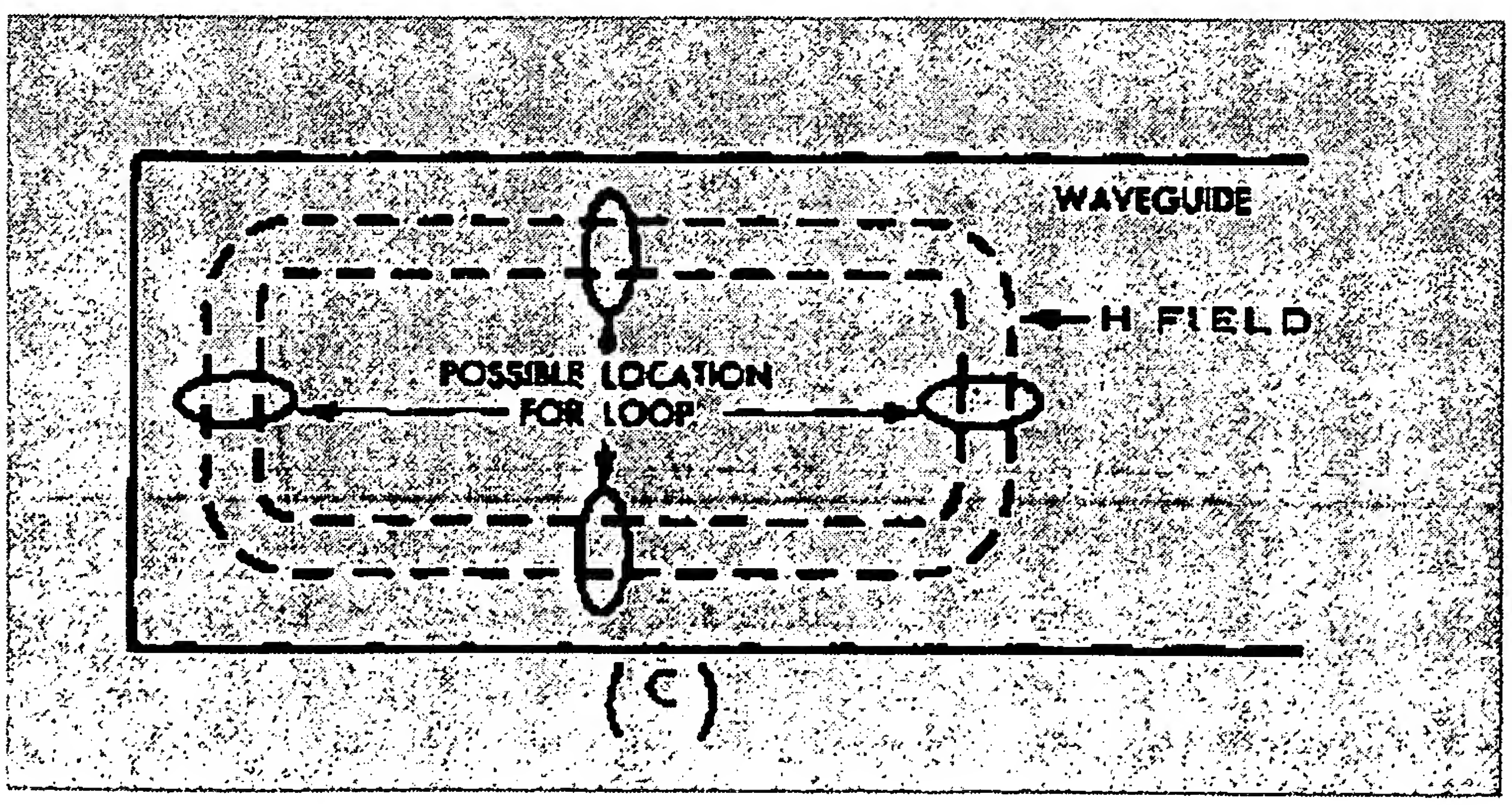


Figure 1-40C. - Loop coupling in a rectangular waveguide.



When less efficient coupling is desired, you can rotate or move the loop until it encircles a smaller number of H lines. When the diameter of the loop is increased, its power-handling capability also increases.

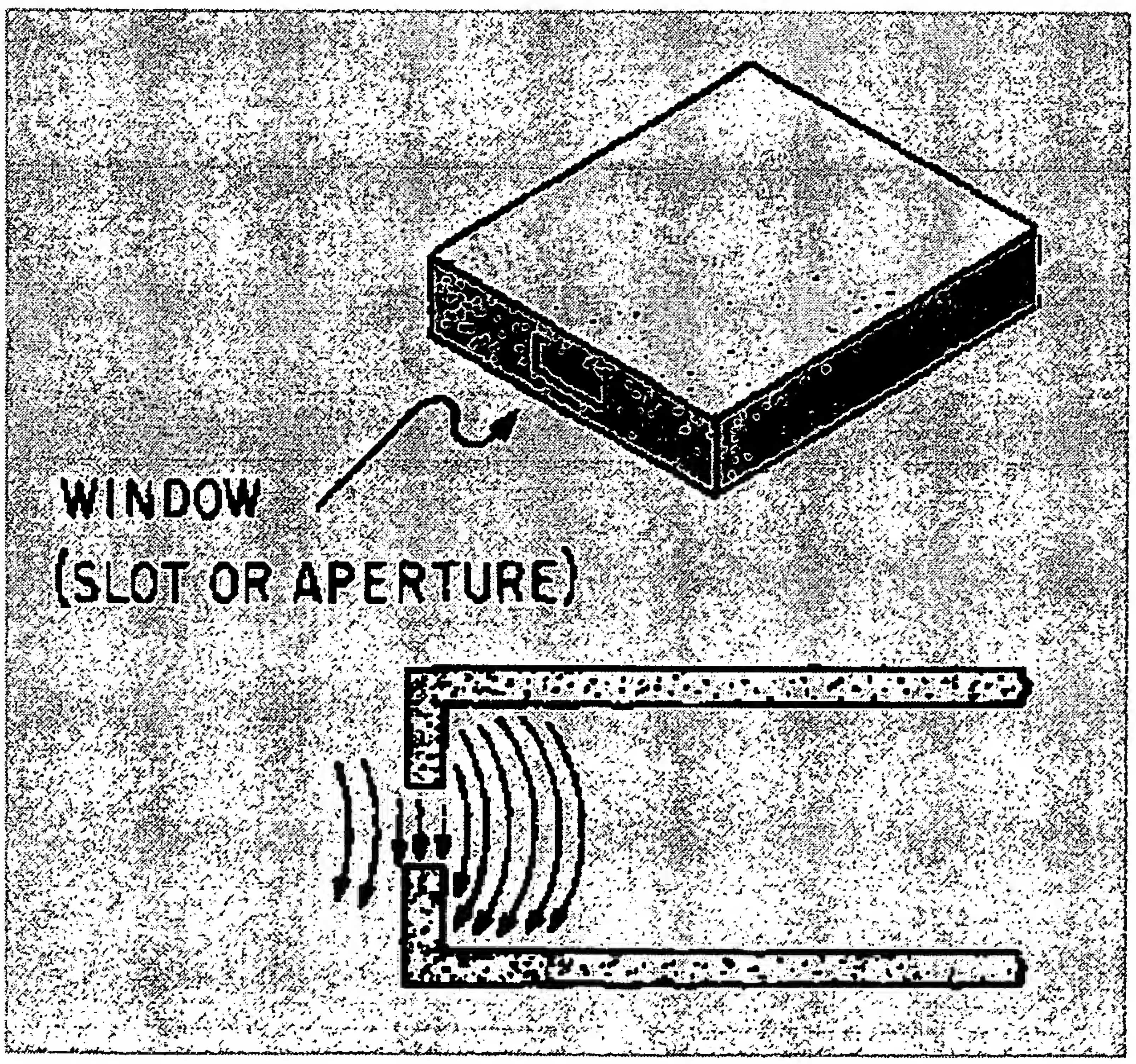
The bandwidth can be increased by increasing the size of the wire used to make the loop.

When a loop is introduced into a waveguide in which an H field is present, a current is induced in the loop. When this condition exists, energy is removed from the waveguide.

Slots or apertures are sometimes used when very loose (inefficient) coupling is desired, as shown in figure 1-41. In this method energy enters through a small slot in the waveguide and the E field expands into the waveguide. The E lines expand first across the slot and then across the interior of the waveguide.

Minimum reflections occur when energy is injected or removed if the size of the slot is properly proportioned to the frequency of the energy.

Figure 1-41. - Slot coupling in a waveguide.



After learning how energy is coupled into and out of a waveguide with slots, you might think that leaving the end open is the most simple way of injecting or removing energy in a waveguide. This is not the case, however, because when energy leaves a waveguide, fields form around the end of the waveguide. These fields cause an impedance mismatch which, in turn, causes the development of standing waves and a drastic loss in efficiency. Various methods of impedance matching and terminating waveguides will be covered in the next

section.

Q.24 What term is used to identify each of the many field configurations that can exist in waveguides? **Answer**
Q.25 What field configuration is easiest to produce in a given waveguide? **Answer**
Q.26 How is the cutoff wavelength of a circular waveguide figured? **Answer**
Q.27 The field arrangements in waveguides are divided into what two categories to describe the various modes of operation? **Answer**
Q.28 The electric field is perpendicular to the "a" dimension of a waveguide in what mode? **Answer**
Q.29 The number of half-wave patterns in the "b" dimension of rectangular waveguides is indicated by which of the two descriptive subscripts? **Answer**
Q.30 Which subscript, in circular waveguide classification, indicates the number of full-wave patterns around the circumference? **Answer**
Q.31 What determines the frequency, bandwidth, and power-handling capability of a waveguide probe? **Answer**
Q.32 Loose or inefficient coupling of energy into or out of a waveguide can be accomplished by the use of what method? **Answer**

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Radiation from probe placed in a waveguide

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When a quarter-wavelength probe is inserted into a waveguide and supplied with microwave energy, it will act as a quarter-wave vertical antenna. Positive and negative wavefronts will be radiated, as shown in figure 1-24. Any portion of the wavefront traveling in the direction of arrow C will rapidly decrease to zero because it does not fulfill either of the required boundary conditions. The parts of the wavefronts that travel in the directions of arrows A and B will reflect from the walls and form reverse-phase wavefronts. These two wavefronts, and those that follow, are illustrated in figure 1-25. Notice that the wavefronts crisscross down the center of the waveguide and produce the same resultant field pattern that was shown in figure 1-23.

Figure 1-24. - Radiation from probe placed in a waveguide.

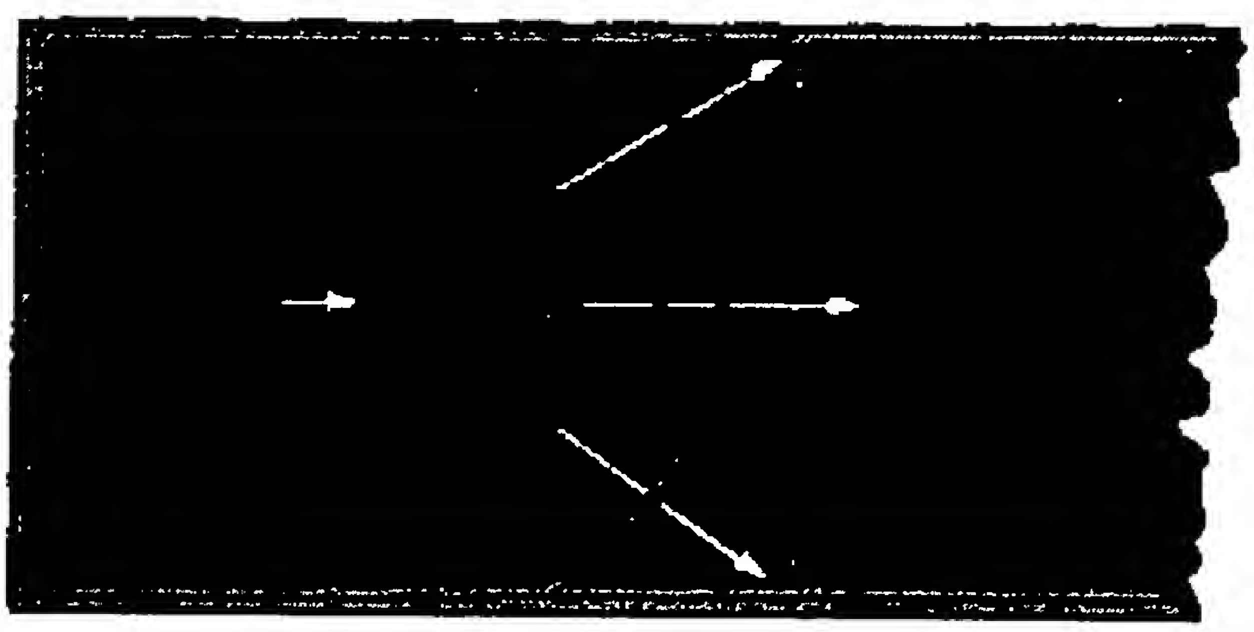


Figure 1-25A. - Wavefronts in a waveguide.

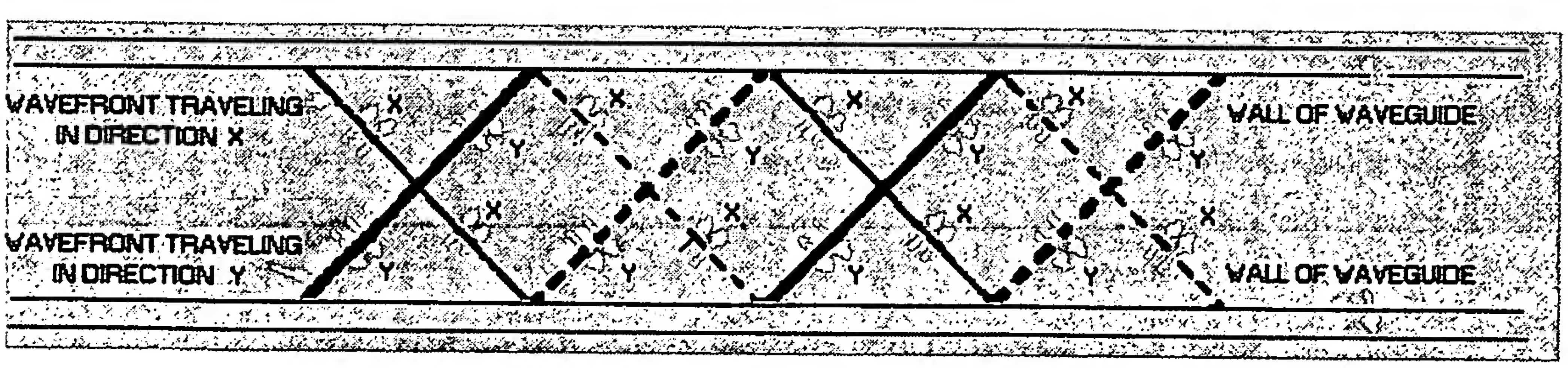
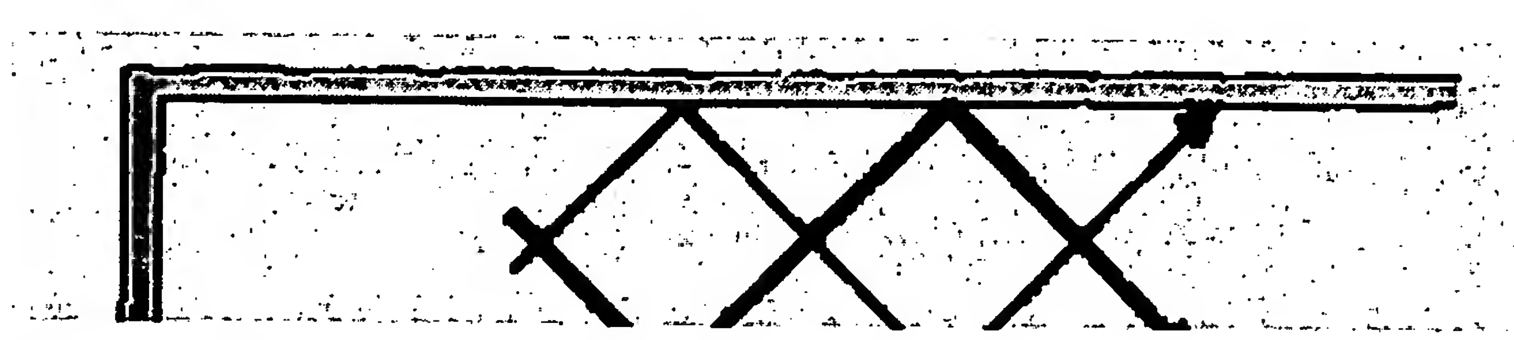


Figure 1-25B. - Wavefronts in a waveguide.



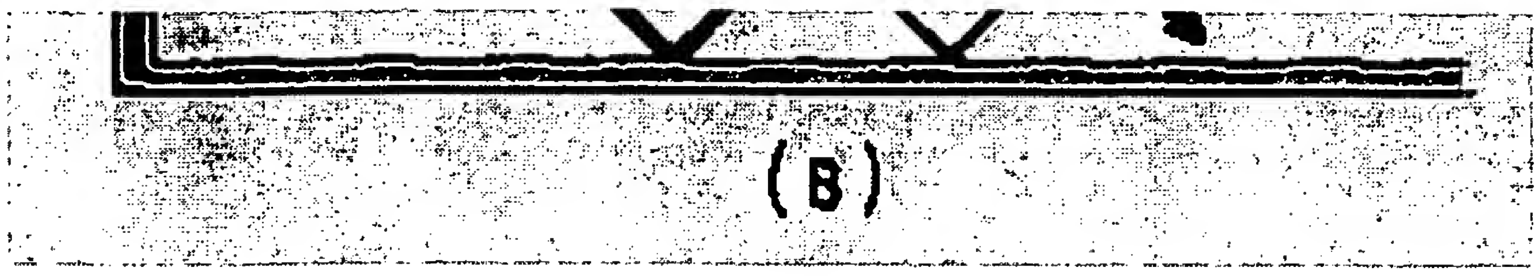
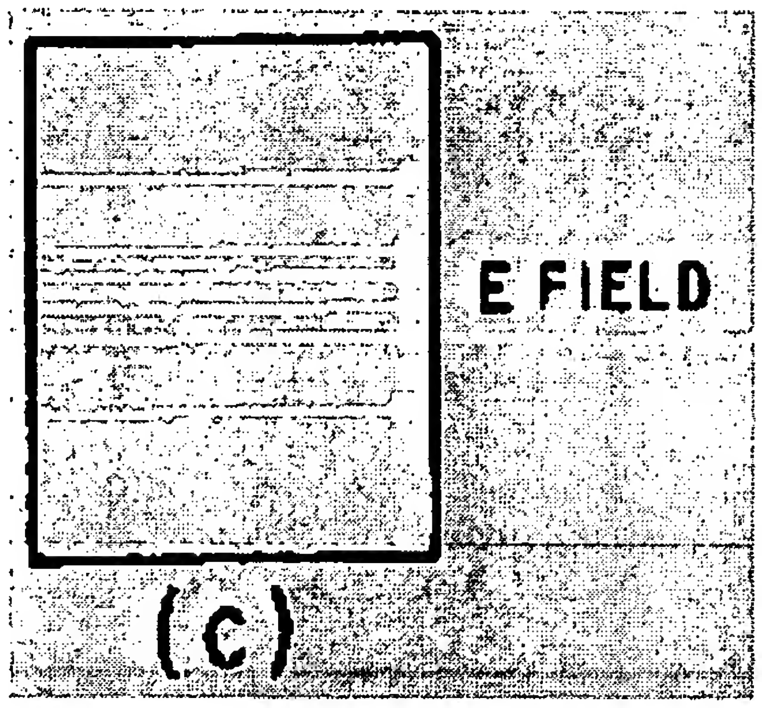
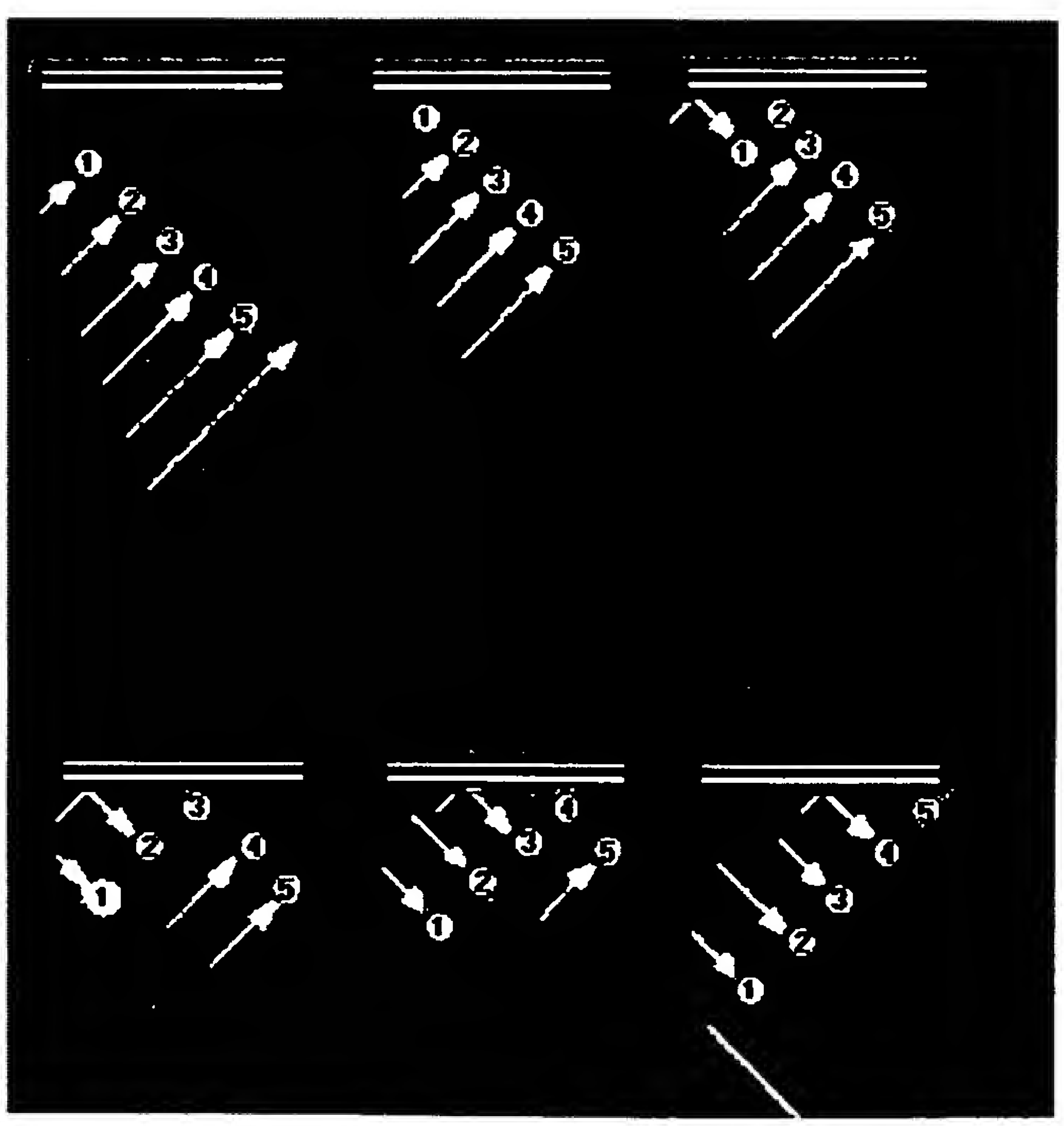


Figure 1-25C. - Wavefronts in a waveguide.



The reflection of a single wavefront off the "b" wall of a waveguide is shown in figure 1-26. The wavefront is shown in view (A) as small particles. In views (B) and (C) particle 1 strikes the wall and is bounced back from the wall without losing velocity. If the wall is perfectly flat, the angle at which it strikes the wall, known as the angle of incidence, is the same as the angle of reflection and are measured perpendicular to the waveguide surface. An instant after particle 1 strikes the wall, particle 2 strikes the wall, as shown in view (C), and reflects in the same manner. Because all the particles are traveling at the same velocity, particles 1 and 2 do not change their relative position with respect to each other. Therefore, the reflected wave has the same shape as the original. The remaining particles as shown in views (D), (E) and (F) reflect in the same manner. This process results in a reflected wavefront identical in shape, but opposite in polarity, to the incident wave.

Figure 1-26. - Reflection of a single wavefront.



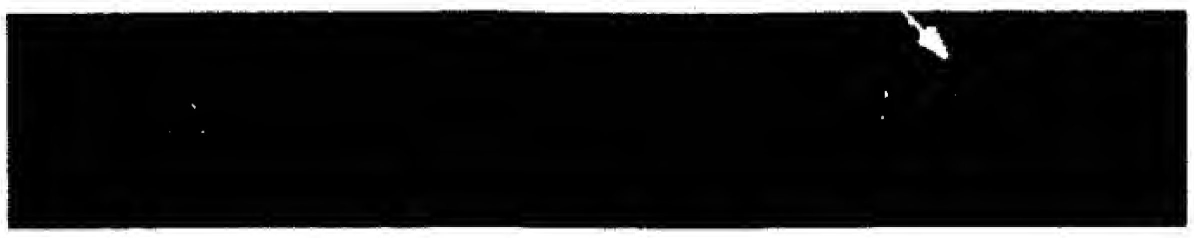


Figure 1-27, views (A) and (B), each illustrate the direction of propagation of two different electromagnetic wavefronts of different frequencies being radiated into a waveguide by a probe. Note that only the direction of propagation is indicated by the lines and arrowheads. The wavefronts are at right angles to the direction of propagation. The angle of incidence (θ) and the angle of reflection (;) of the wavefronts vary in size with the frequency of the input energy, but the angles of reflection are equal to each other in a waveguide. The CUTOFF FREQUENCY in a waveguide is a frequency that would cause angles of incidence and reflection to be zero degrees. At any frequency below the cutoff frequency, the wavefronts will be reflected back and forth across the guide (setting up standing waves) and no energy will be conducted down the waveguide.

Figure 1-27A. - Different frequencies in a waveguide.

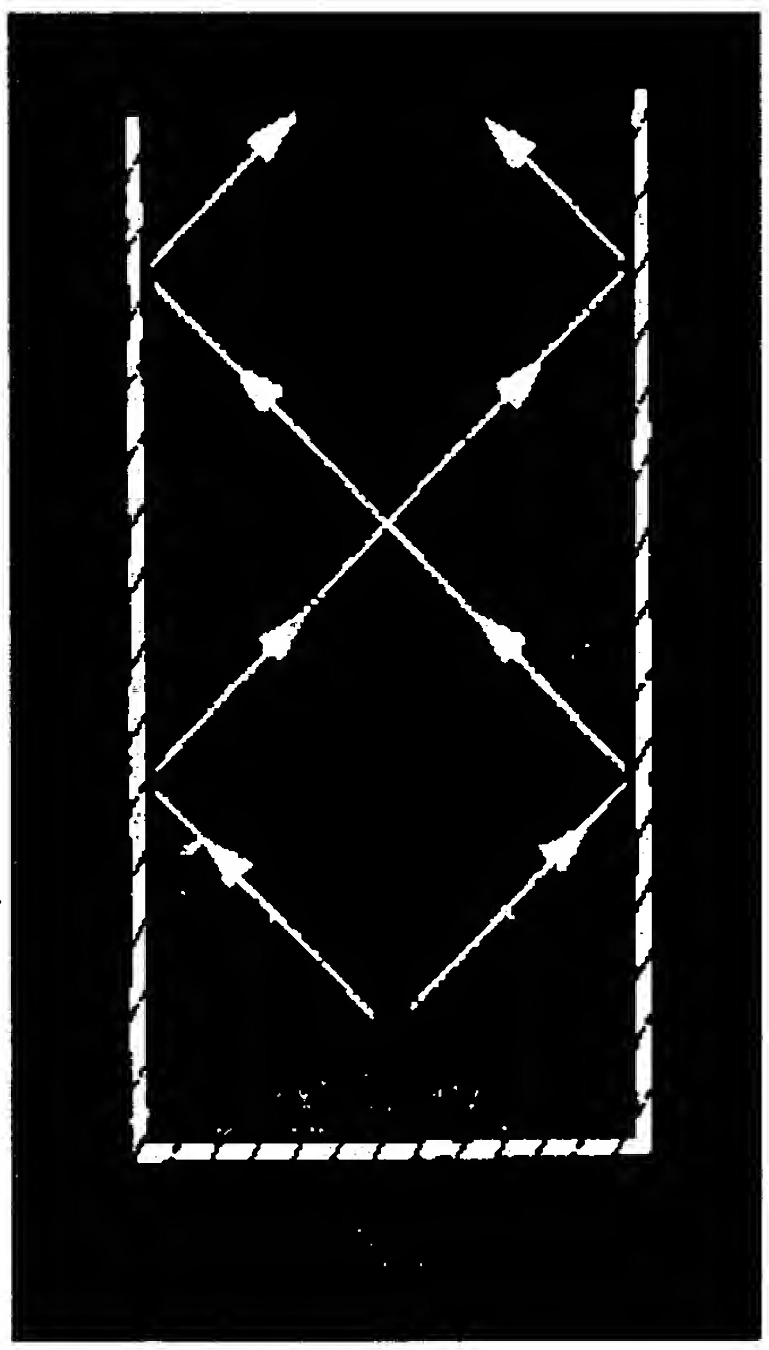
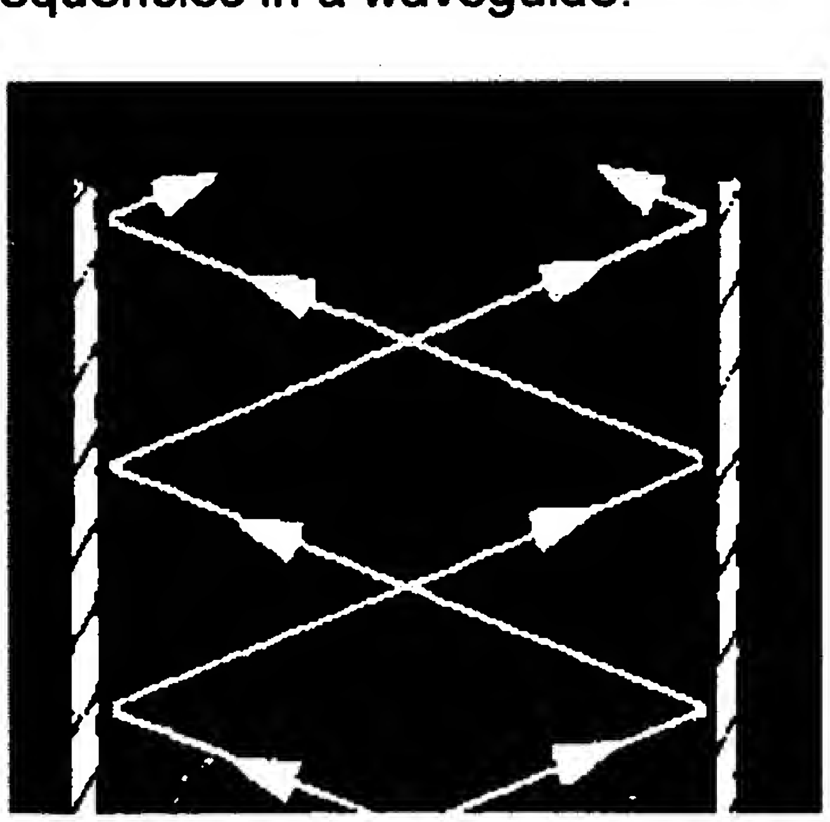
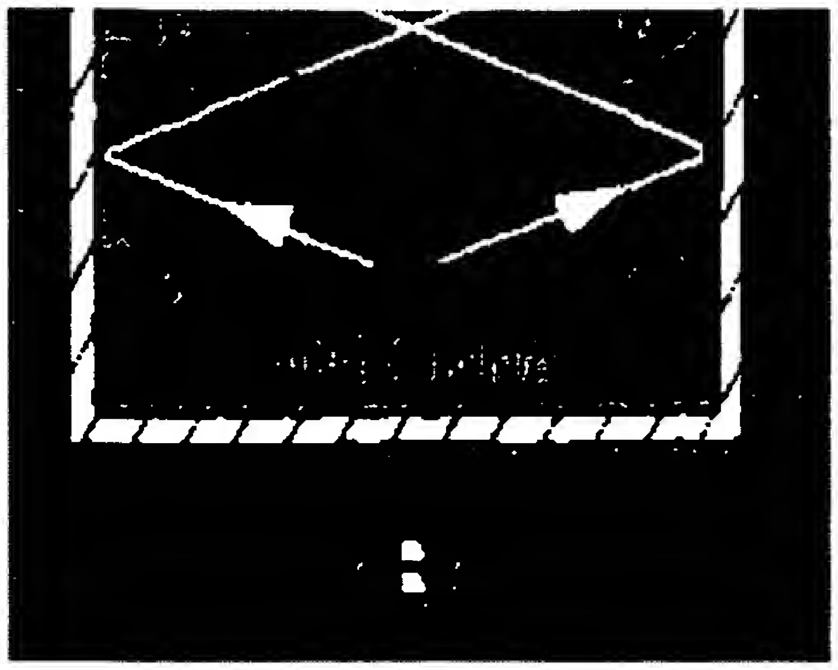


Figure 1-27B. - Different frequencies in a waveguide.





The velocity of propagation of a wave along a waveguide is less than its velocity through free space (speed of light). This lower velocity is caused by the zigzag path taken by the wavefront. The forward-progress velocity of the wavefront in a waveguide is called GROUP VELOCITY and is somewhat slower than the speed of light.

The group velocity of energy in a waveguide is determined by the reflection angle of the wavefronts off the "b" walls. The reflection angle is determined by the frequency of the input energy. This basic principle is illustrated in figure 1-28. As frequency is decreased, the reflection angle decreases causing the group velocity to decrease. The opposite is also true; increasing frequency increases the group velocity.

Figure 1-28A. - Reflection angle at various frequencies. LOW FREQUENCY

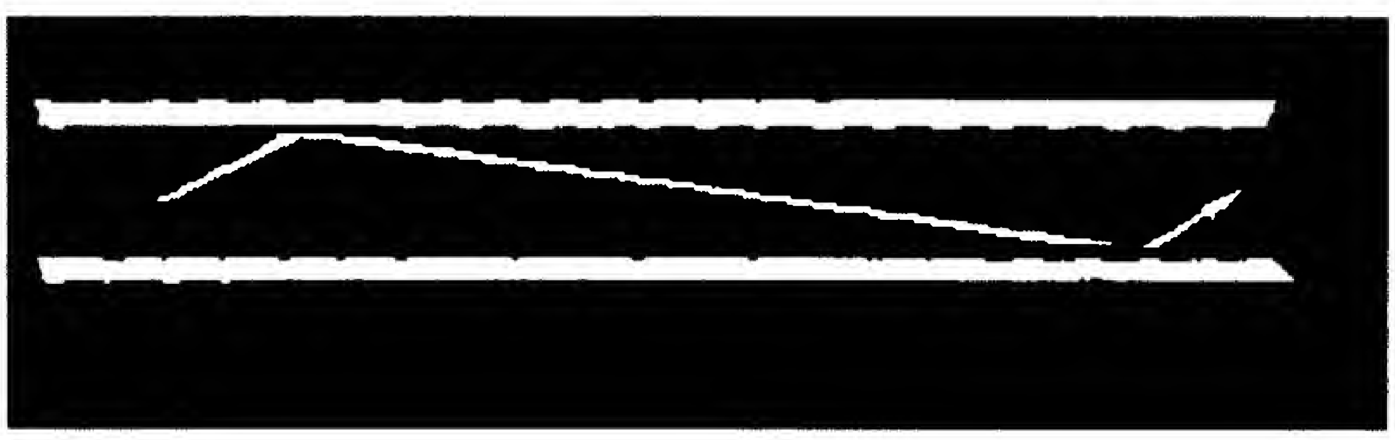


Figure 1-28B. - Reflection angle at various frequencies. MEDIUM FREQUENCY

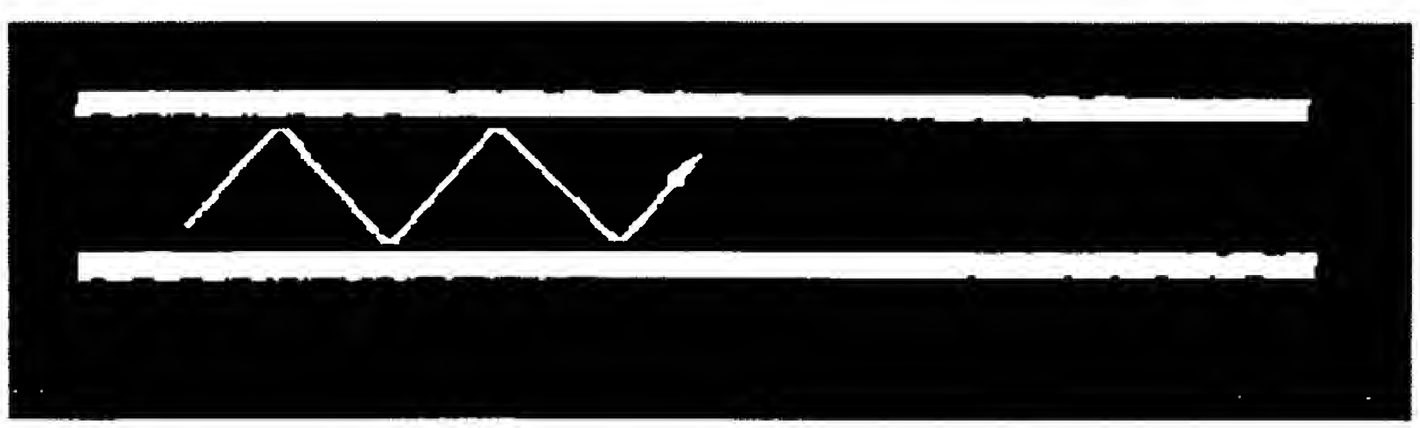
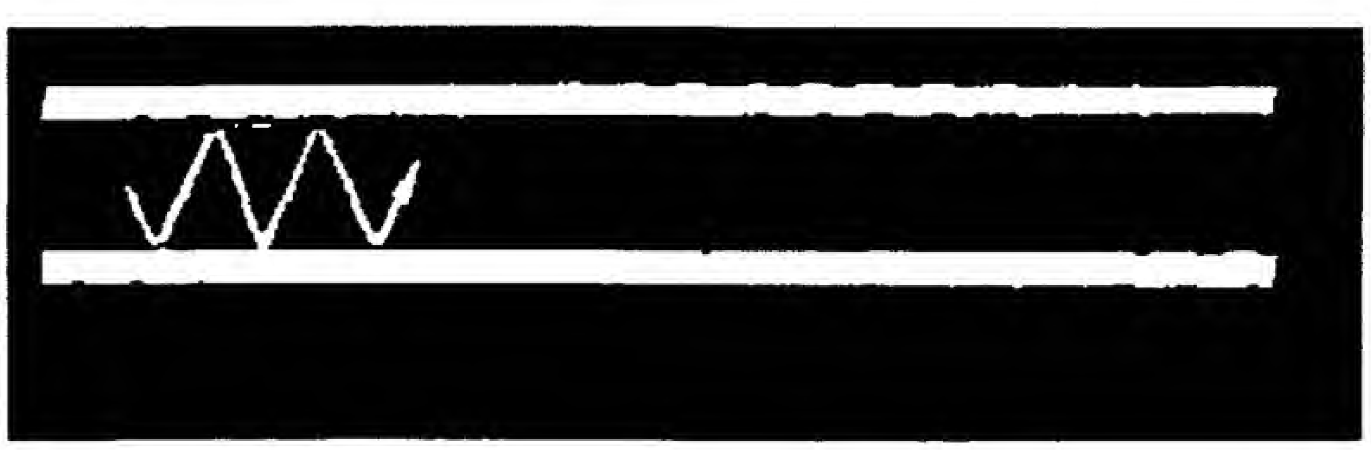


Figure 1-28C. - Reflection angle at various frequencies. HIGH<?Pub Caret> FREQUENCY



Q.14 What interaction causes energy to travel down a waveguide? **Answer**

Q.15 What is indicated by the number of arrows (closeness of spacing) used to represent an electric field? **Answer**

Q.16 What primary condition must magnetic lines of force meet in order to exist? **Answer**

Q.17 What happens to the H lines between the conductors of a coil when the conductors are close together? **Answer**

Q.18 For an electric field to exist at the surface of a conductor, the field must have what angular relationship to the conductor? **Answer**

Q.19 When a wavefront is radiated into a waveguide, what happens to the portions of the wavefront that do not satisfy the boundary conditions? **Answer**

Q.20 Assuming the wall of a waveguide is perfectly flat, what is the angular relationship between the angle of incidence and the angle of reflection? **Answer**

Q.21 What is the frequency called that produces angles of incidence and reflection that are perpendicular to the waveguide walls? **Answer**

Q.22 Compared to the velocity of propagation of waves in air, what is the velocity of propagation of waves in waveguides? **Answer**

Q.23 What term is used to identify the forward progress velocity of wavefronts in a waveguide? **Answer**

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